Detailed flow, hydrometeor and lightning characteristics of an isolated, hail producing thunderstorm during COPS

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Results from previous studies of IOP 8b (15 July 2007)

Observation

- Kottmeier et al. 2008, MetZet
- Aoshima et al. 2008, MetZet
- Kalthoff et al. 2009, AR
- Behrendt et al. 2011, QJRMS

Modelling

- Barthlott et al. 2009, AR
- Kirshbaum et al. 2010, JAS
- Richard et al. 2011, QJRMS
- Barthlott et al. 2011, QJRMS

- General observation results with special focus on convection initiation → ← no deep convection by using COSMO-DE but triggering of convection matches well
- Evaluation of triggering mechanism (radar convergence line) → Intercomparison of different model results
- Evaluation of moist condition → Comparison with observed moisture, changing of Meso-NH-model parameters

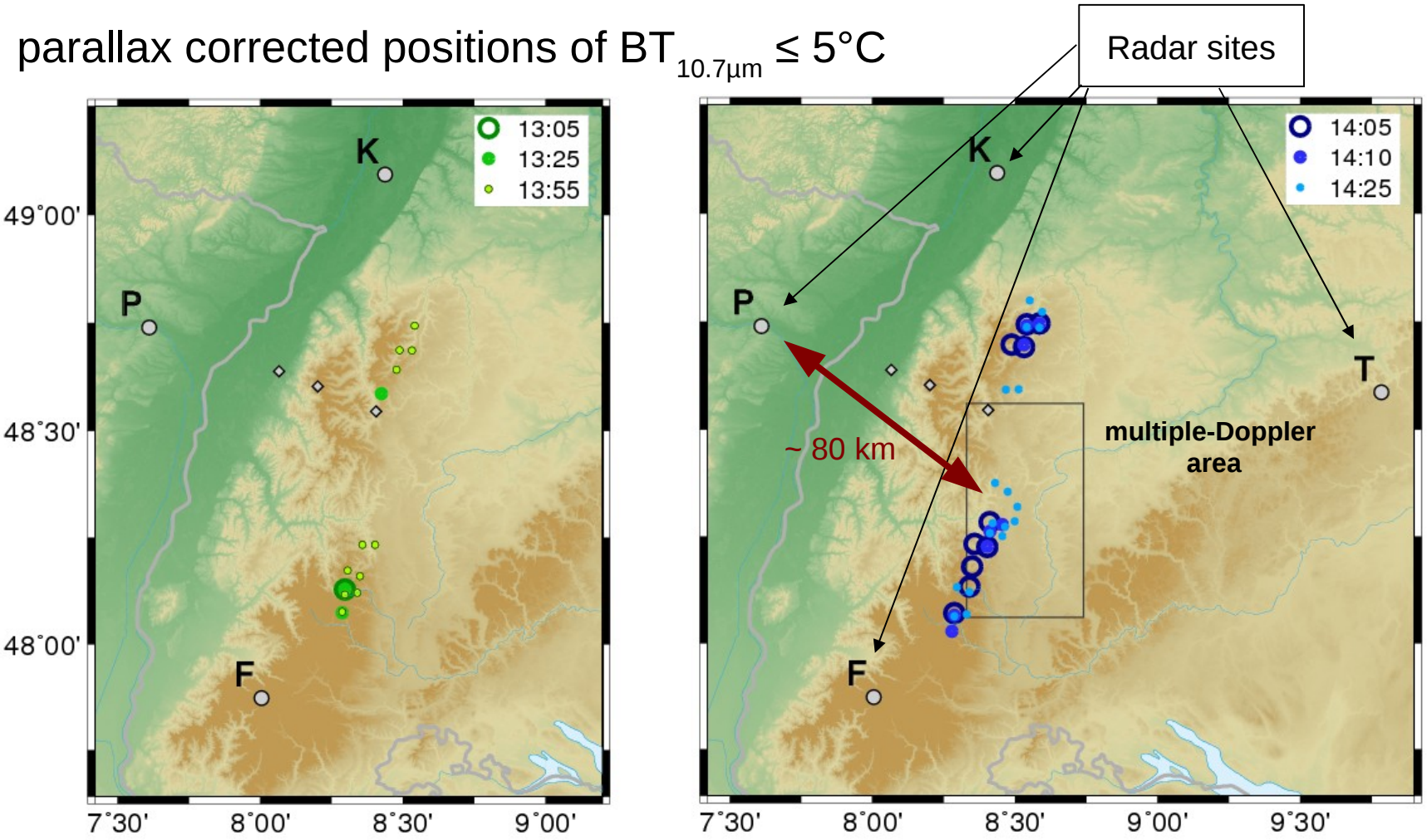
current step: evaluation of mature state and dissipation

Approach: Synergy of sensors

- Multiple-Doppler radar analysis of 15 July 2007, additional validation with photos, lightning and MSG data
- Development of cloud-top height evaluated from radar and MSG data
- Analysis of microphysics of clouds by using polarimetric radar data

Initiation: Horizontal development

parallax corrected positions of $BT_{10.7\mu m} \leq 5°C$



Life cycle and vertical development

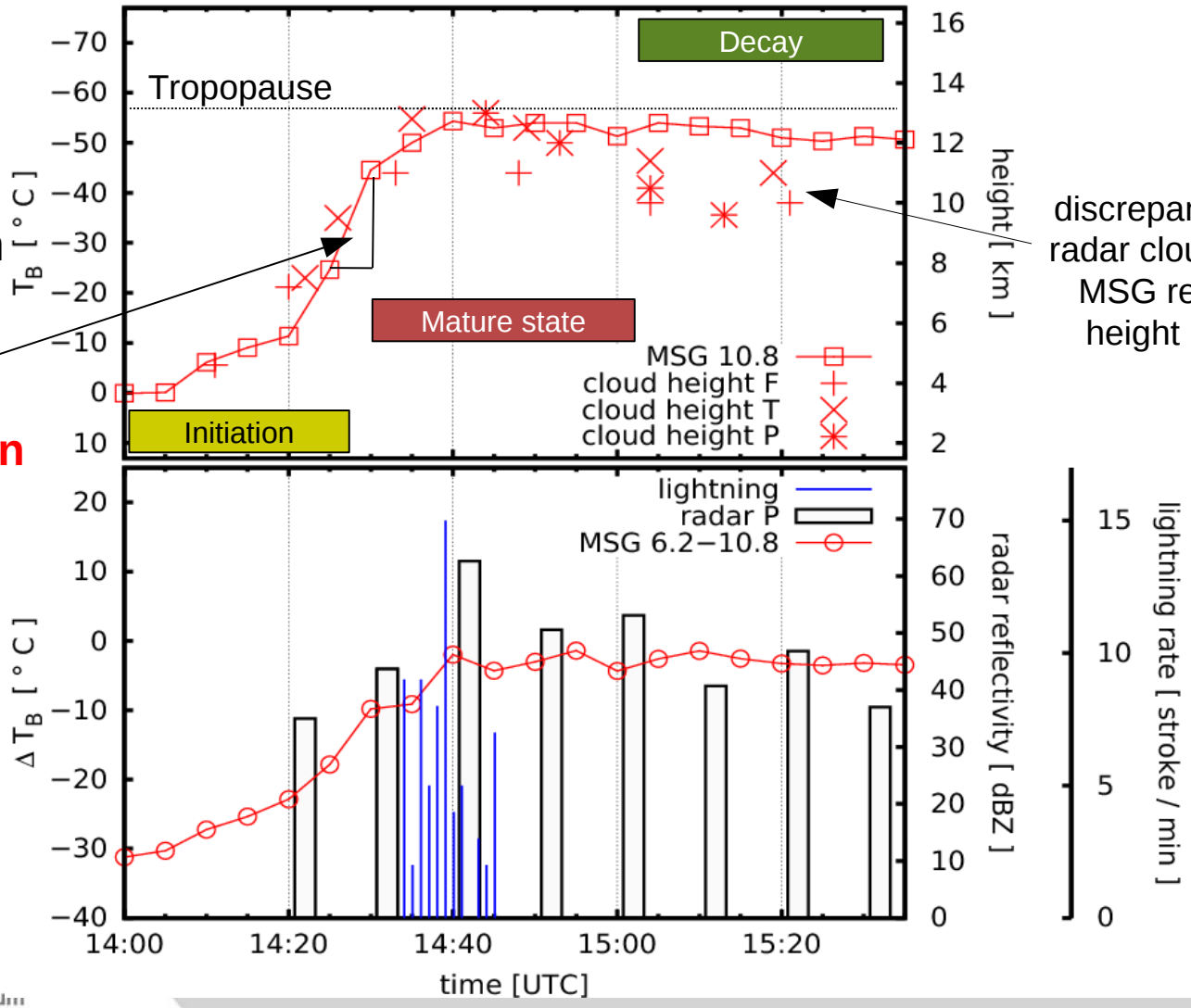
lapse rate:

0.6 K per 100 m

3 km at 5 min

-> vertical motion

~ 10 m/s



discrepancy between radar cloud height and MSG related cloud height (ice shield)

Life cycle and vertical development

lapse rate:

0.6 K per 100 m

3 km at 5 min

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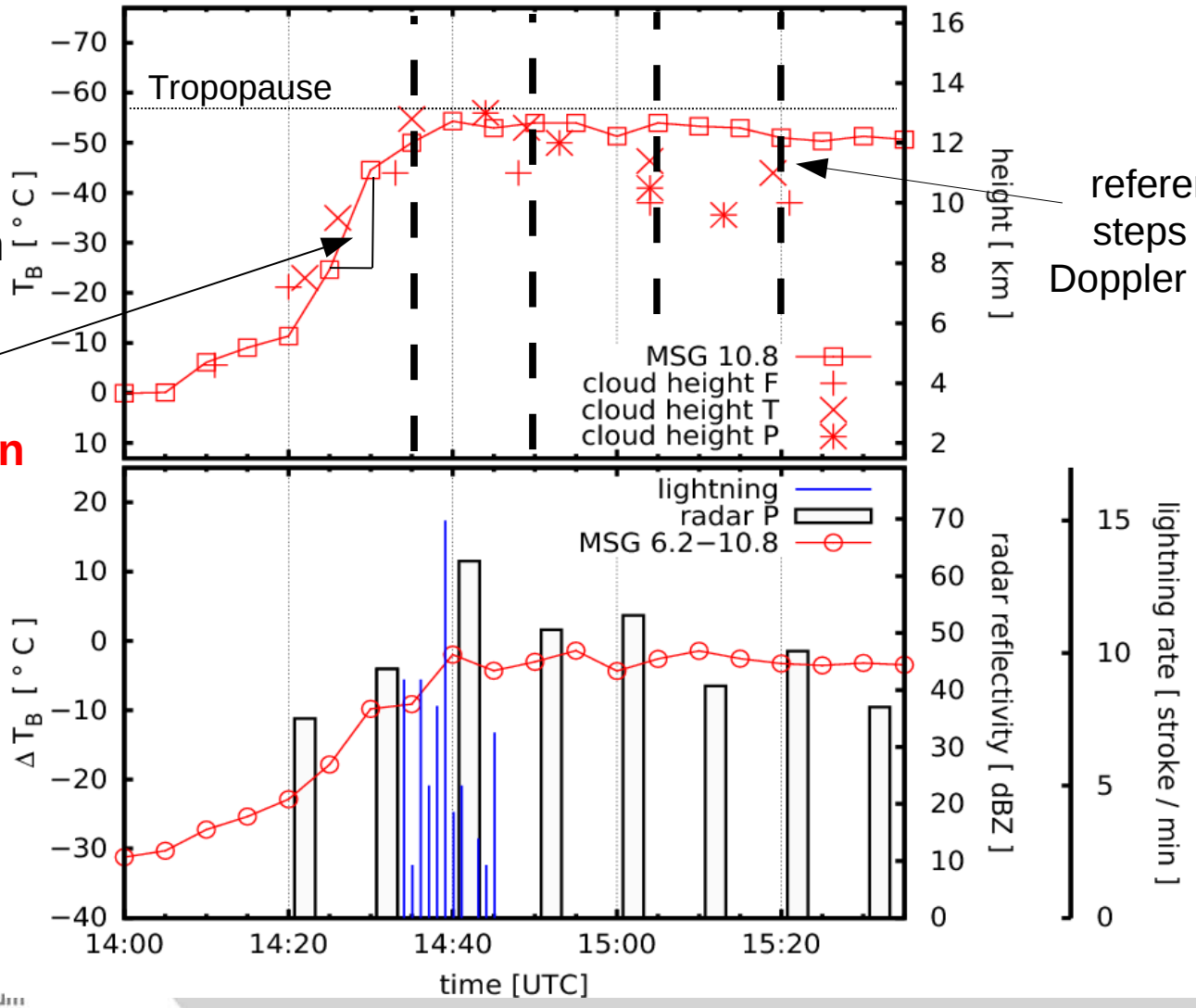
~ 10 m/s



reference time steps for triple Doppler calculation

Data radar volume scan time intervals

Feldberg radar	Türkheim radar	Karlsruhe radar	reference time for Multiple Doppler calculation
14:30 – 14:37	14:30 – 14:37	14:30 – 14:34	14:35
14:45 – 14:52	14:45 – 14:52	14:50 – 14:54	14:50
15:00 – 15:07	15:00 – 15:07	15:00 – 15:04	15:05
15:15 – 15:22	15:15 – 15:22	15:20 – 15:24	15:20

Validation case

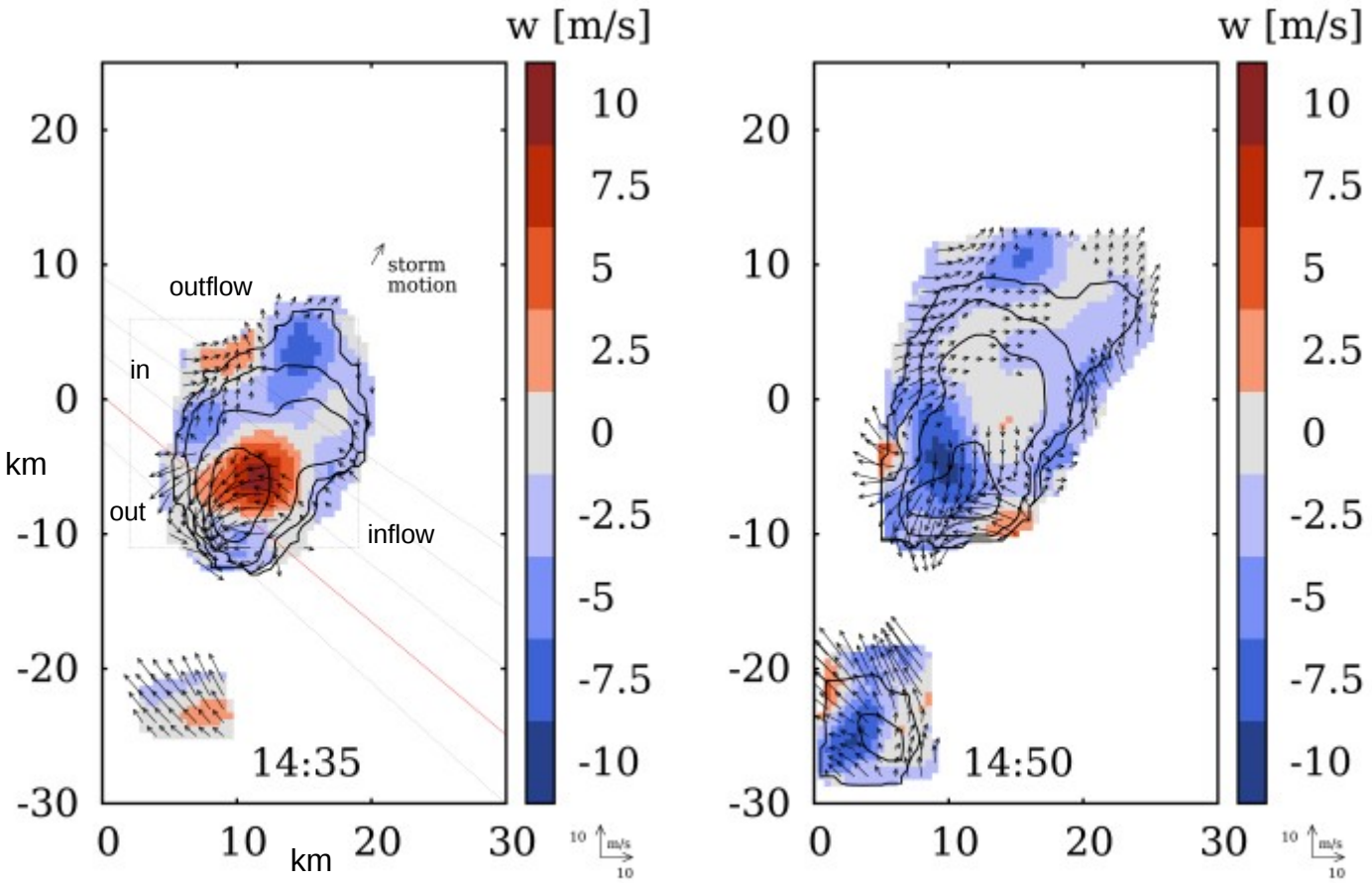
POLDIRAD RHI scan	Feldberg radar	Türkheim radar	Karlsruhe radar	reference time for Multiple Doppler calculation
14:43 - 14:45	14:45 – 14:52	14:45 – 14:52	14:30 – 14:34	14:43

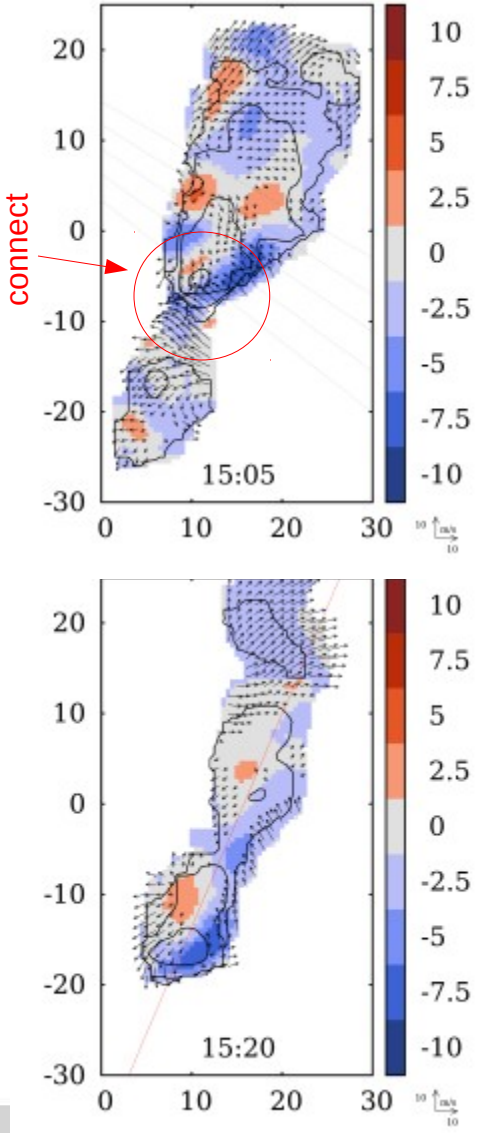
Method — Multiple Doppler calculation

- radar data interpolation by using REORDER (by NCAR)
  - GRID distance in all 3 dimensions: 500m (tested: 300m, 1km)
  - Cressman weighting scheme
  - Determination of storm motion (best overlap of reflectivity)

- multiple doppler calculation by using CEDRIC (by NCAR)
  - calculation horizontal wind components u,v
  - smoothing of wind field
  - calculation of vertical wind by using variation integration procedure with boundary conditions

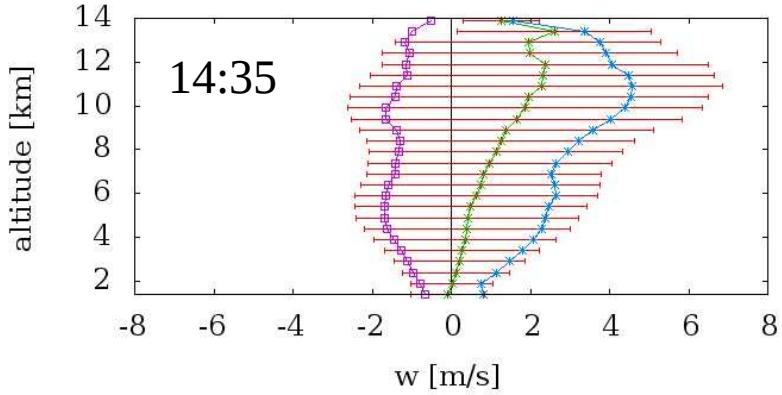
Result Mid cloud flow structure at 5 km (msl)

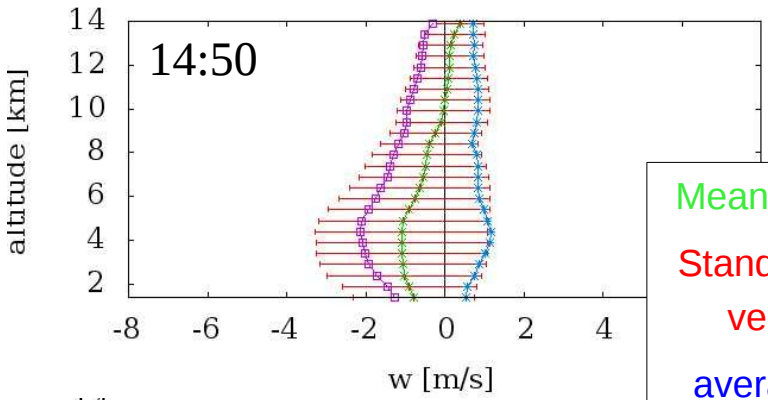


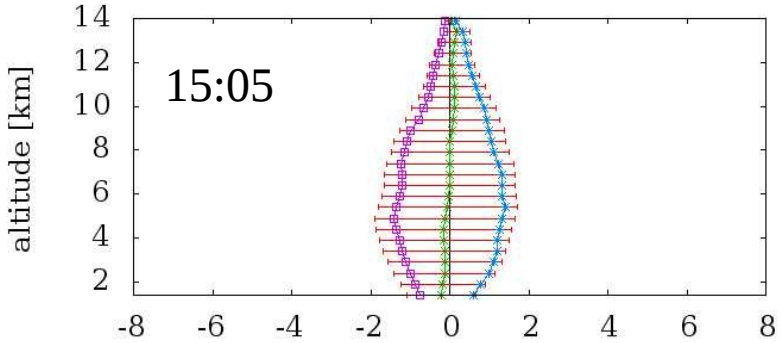


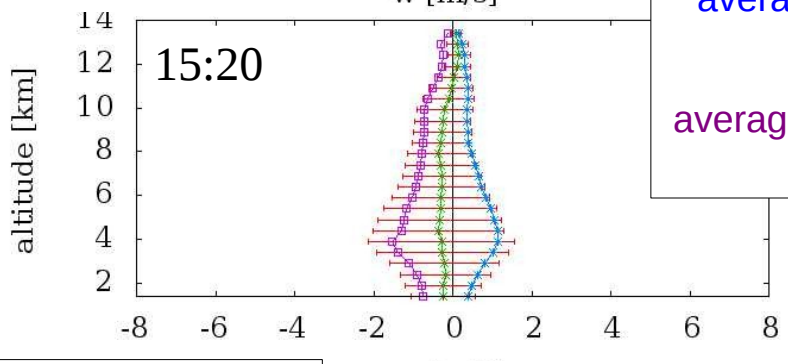
- Contour of reflectivity (10 dbZ interval, starting from 10 dBZ)
- Horizontal wind vectors relative to the storm motion
- updraft downdraft

Statistics: Vertical wind from triple Doppler









Mean vertical velocity

Standard deviation of vertical velocity

average of updrafts (w>0)

average of downdrafts (w<0)

- Updraft higher than downdraft at the early phase (14:35)
- Dominating wind direction changes from updraft to downdraft: decreasing of storm intensity
- Decreasing of absolute vertical wind speed indicate decay state (15:20)

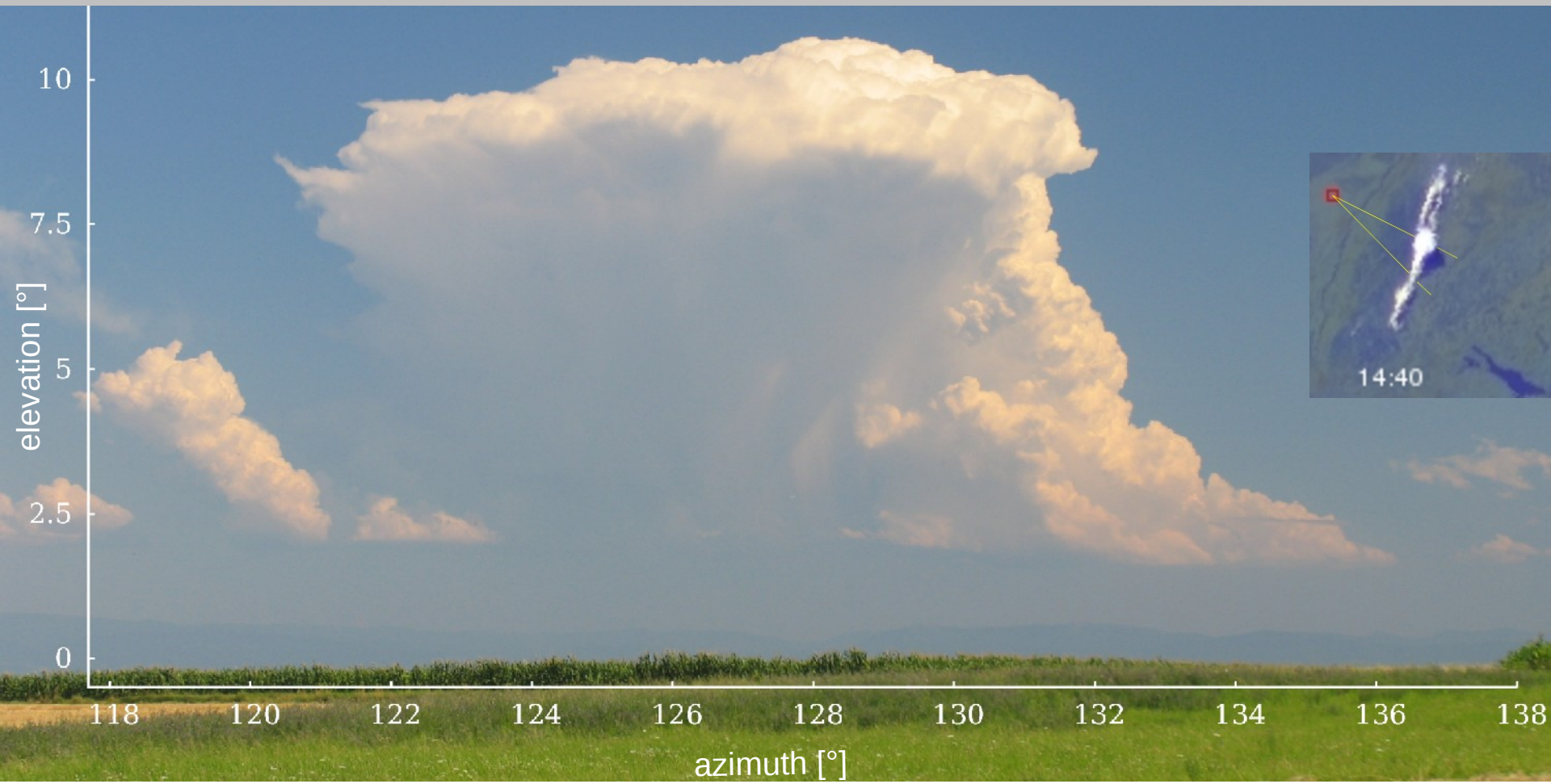
- Mean values and standard deviation decreases at top and bottom (influence of boundary condition)
- Low border limited to 1.7 km: radar beam cannot reach the ground

Validation

first photo from serie:

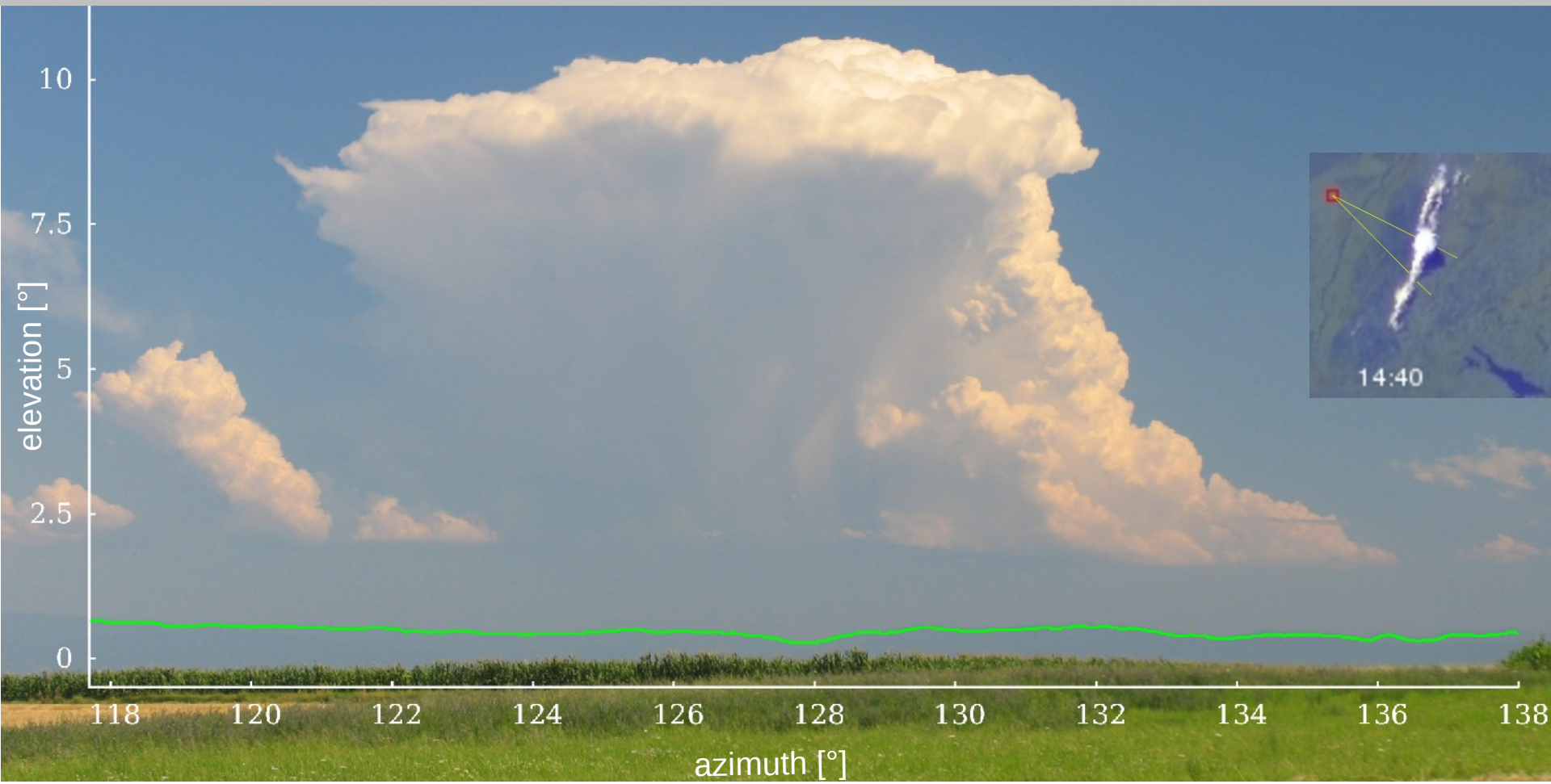
timestamp: 14:43 UTC location: POLDIRAD

Validation



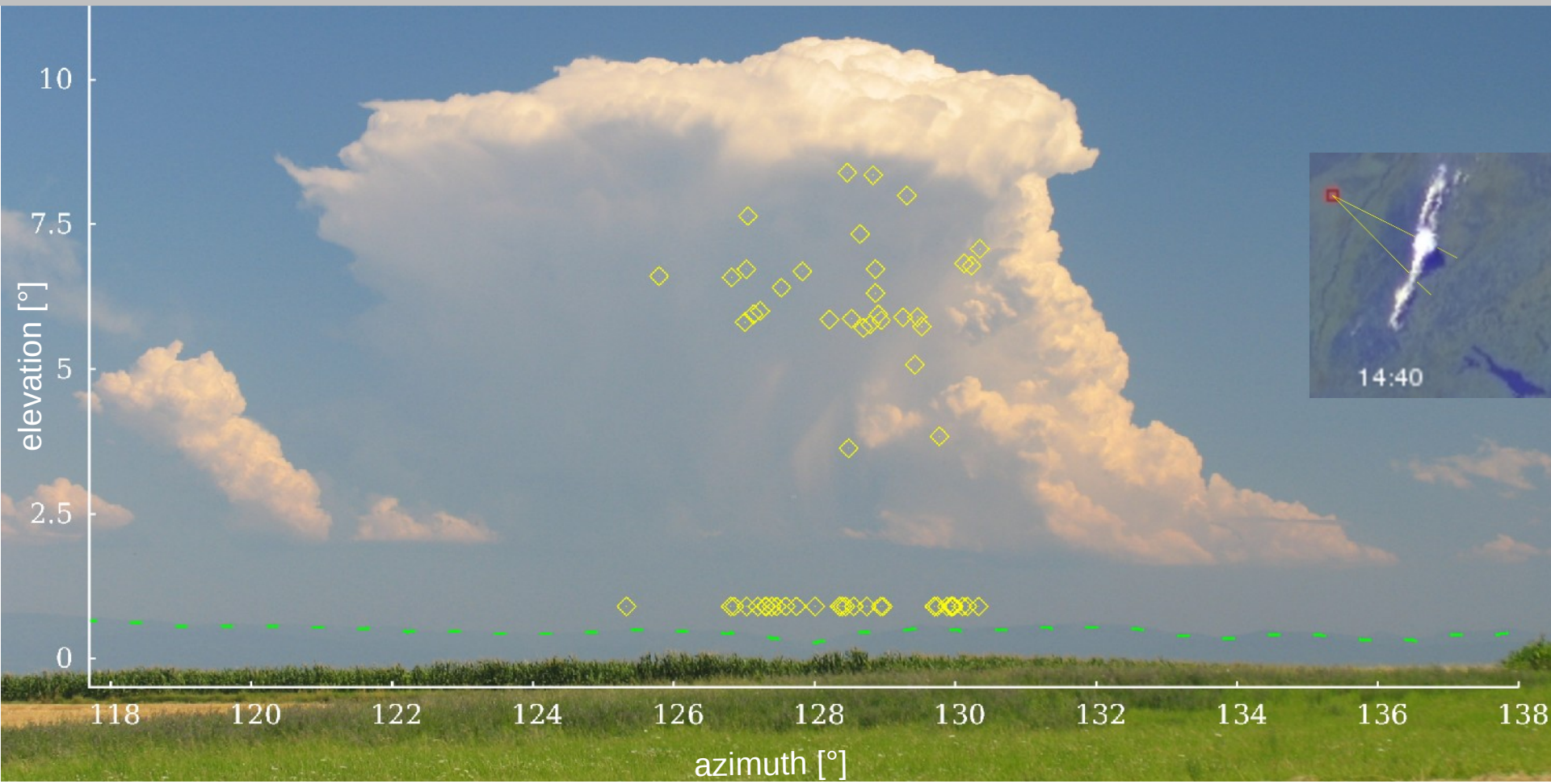
add scale: elevation, azimuth

Validation



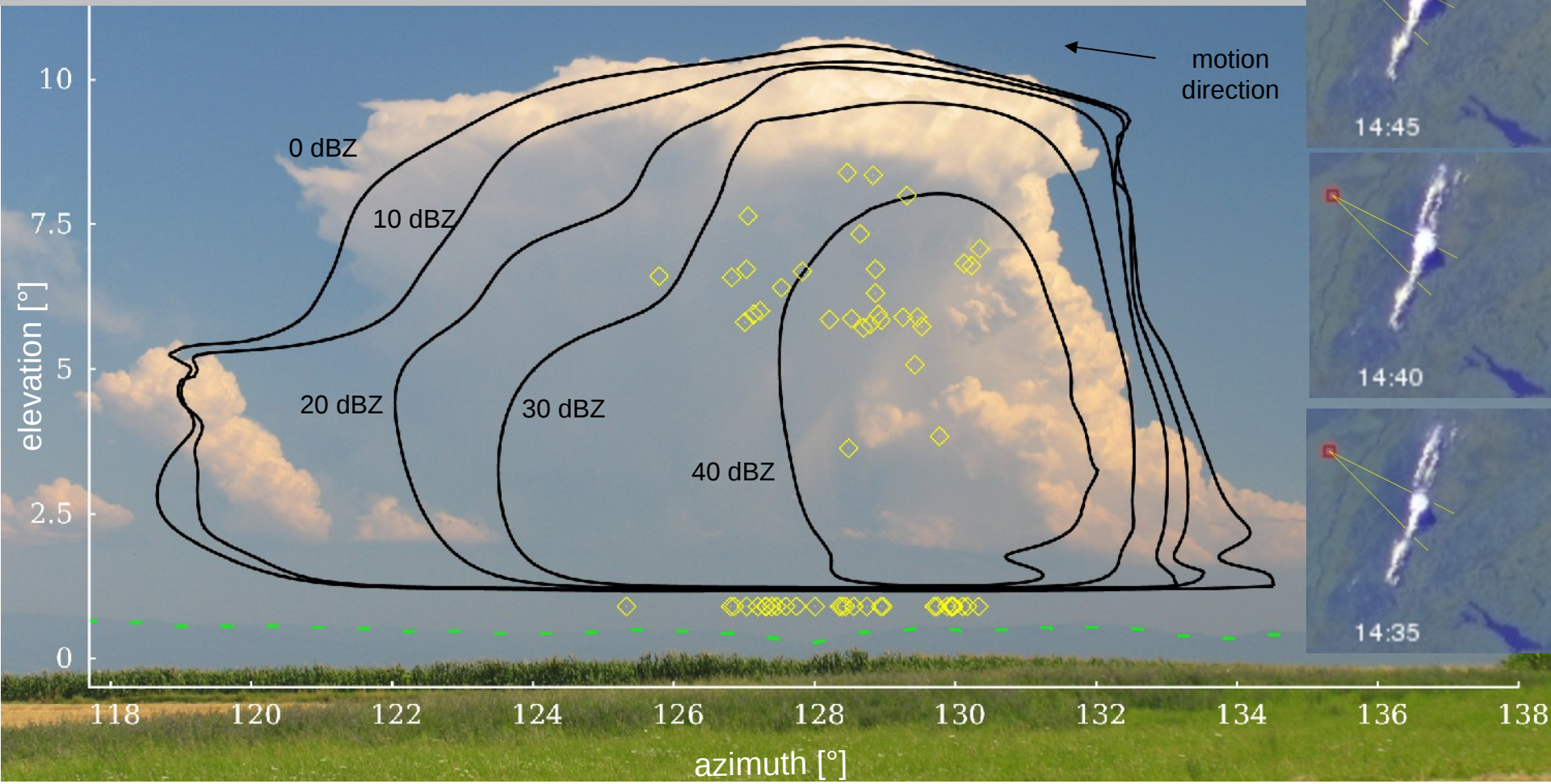
verify: Black Forest silhouette from SRTM topography data

Validation



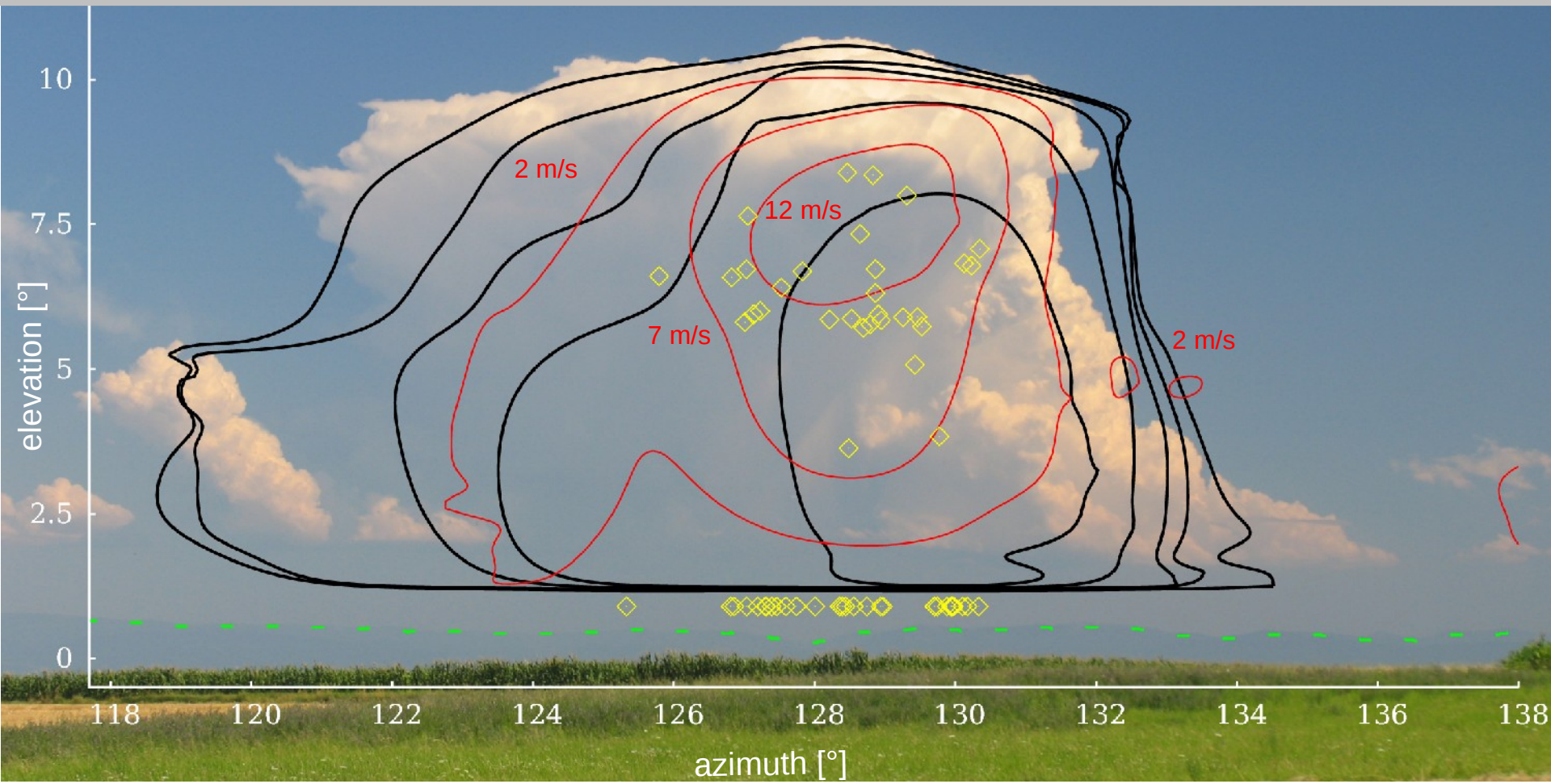
add all lightning locations (cloud and ground stokes) 14:34 – 14:45 UTC
photo time: 14:43 UTC

Validation



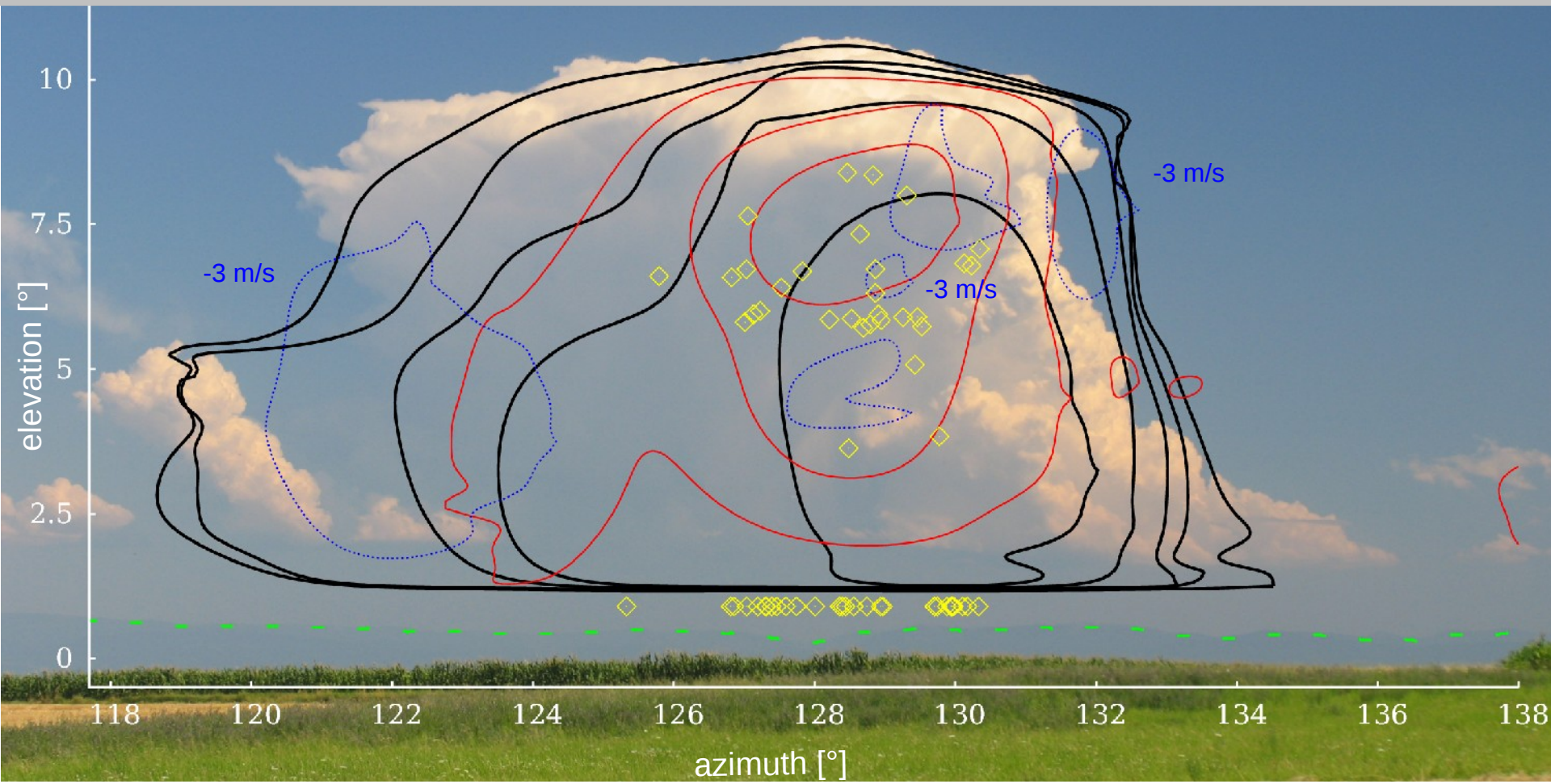
Reflectivity composit from triple-Doppler analysis
at 14:35 UTC (7 minutes before the photo was taken)

Validation



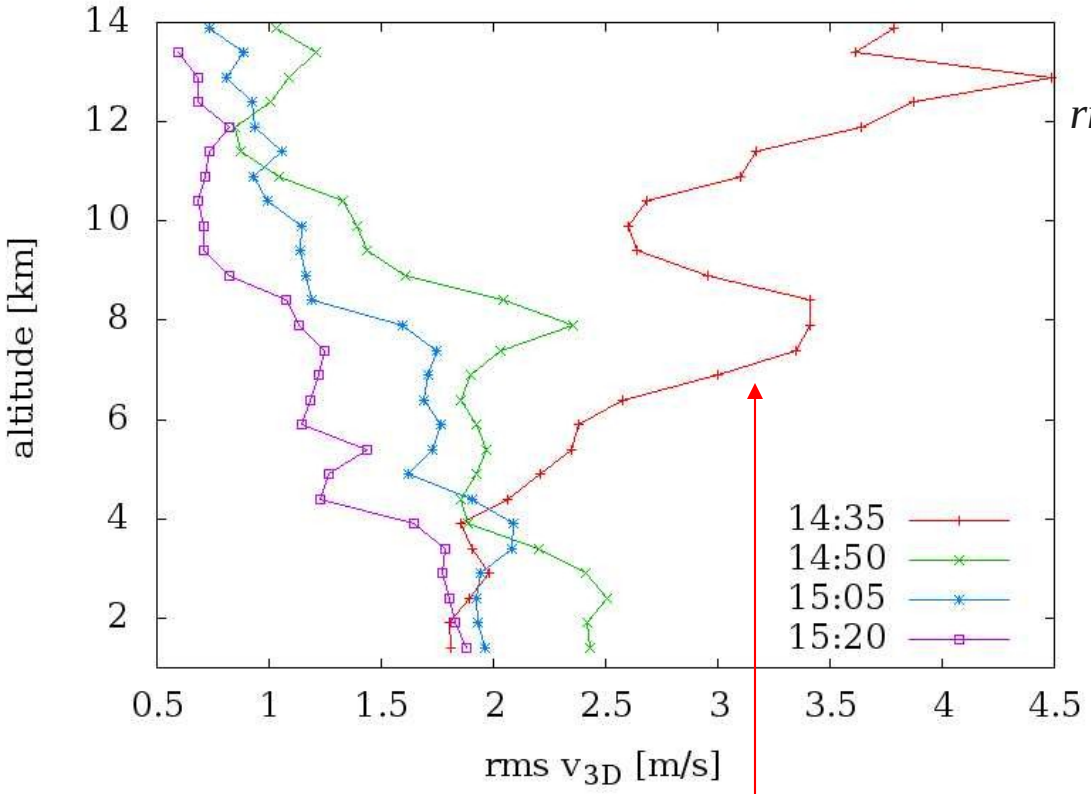
maximum updraft in line of sight
from multiple-Doppler analysis

Validation



maximum downdraft in line of sight
from multiple-Doppler analysis

Consistency check for triple Doppler results



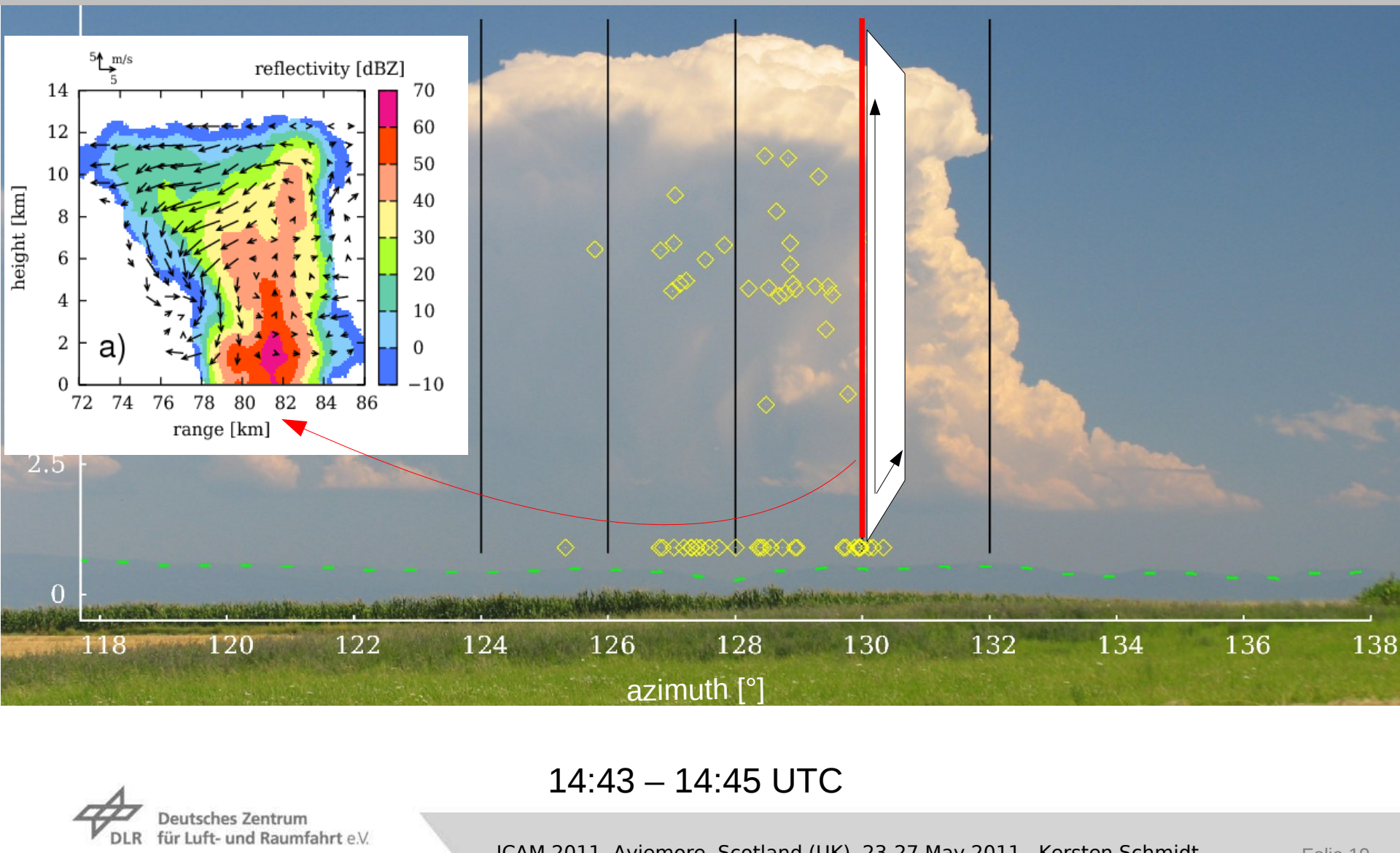
$$rms\ v_{3D} = \sqrt{\frac{1}{n}\sum (v_{r\ Measured}^{i} - v_{r\ 3D}^{i})^2}$$

measured radial velocity from each radar site

derived radial component corresponding to radar site from 3D triple Doppler calculation

Higher dynamics (e.g. more turbulence) in the early Mature state?

Scan position of POLDIRAD RHI scans



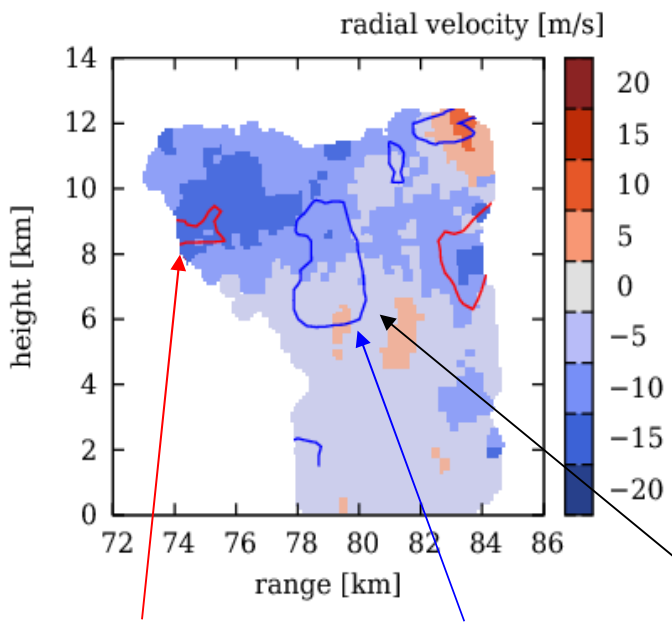
14:43 – 14:45 UTC

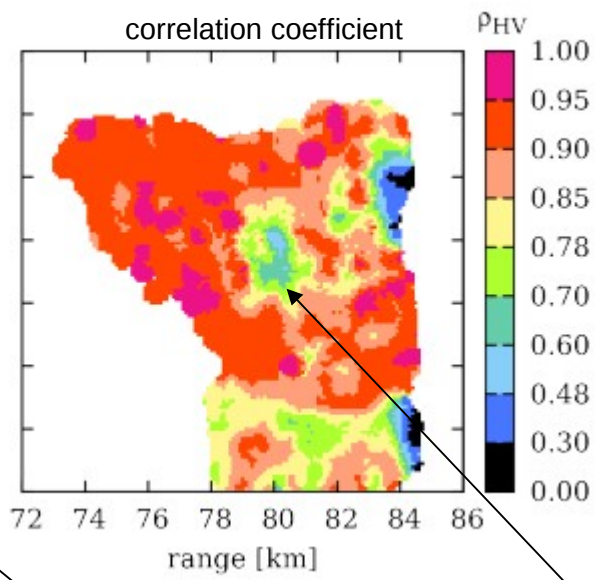
Quality check by using POLDIRAD

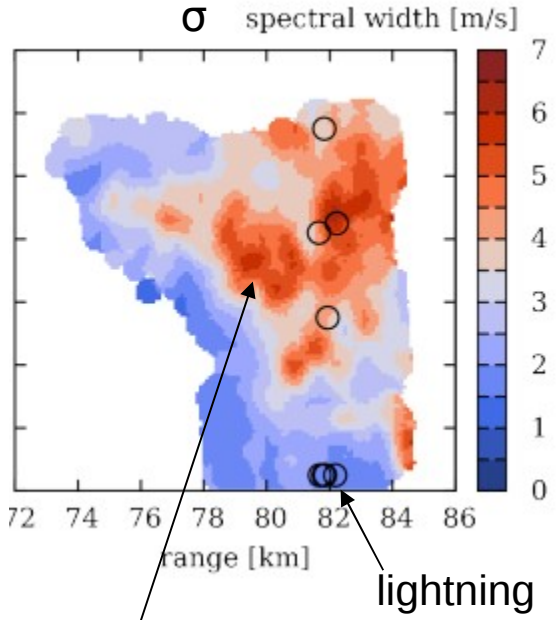
Measured and retrieved radial velocities v_r

low ρ_{HV} : high particle variation in type, shape and orientation

high σ: broad range of radial velocity values







retrieved v_r

5 m/s higher than measured

retrieved v_r

5 m/s lower than measured

main part of discrepancy corresponds with occurrences of turbulence denoted by low ρ_{HV} and high spectral width

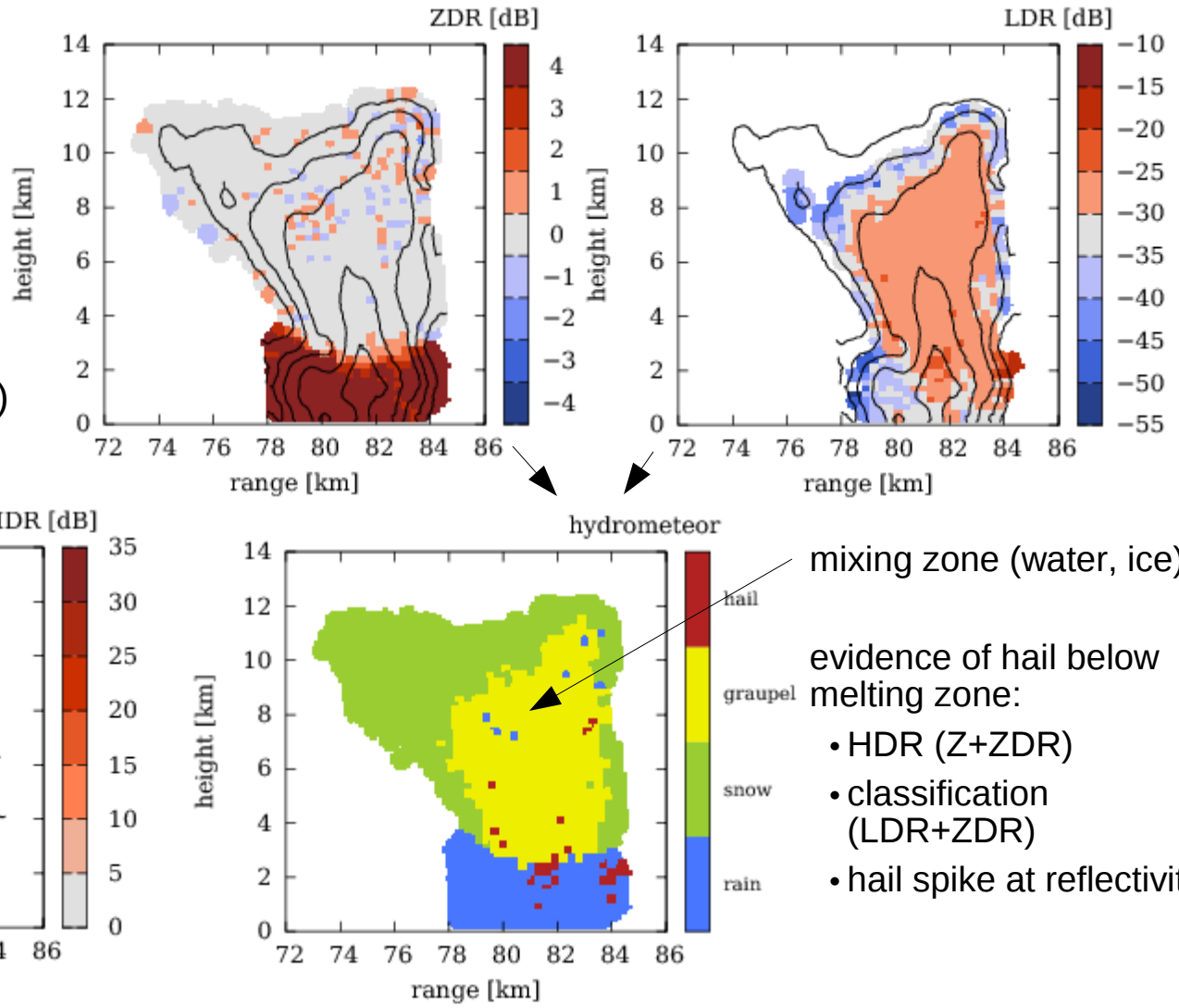
Estimation of hydrometeor content

Estimation of hydro-meteors by only using of ZDR and LDR after Höller et al. 1994

Comparison:

Estimation of hail signal (HDR) by using ZDR and Z

after Aydin et al. 1986

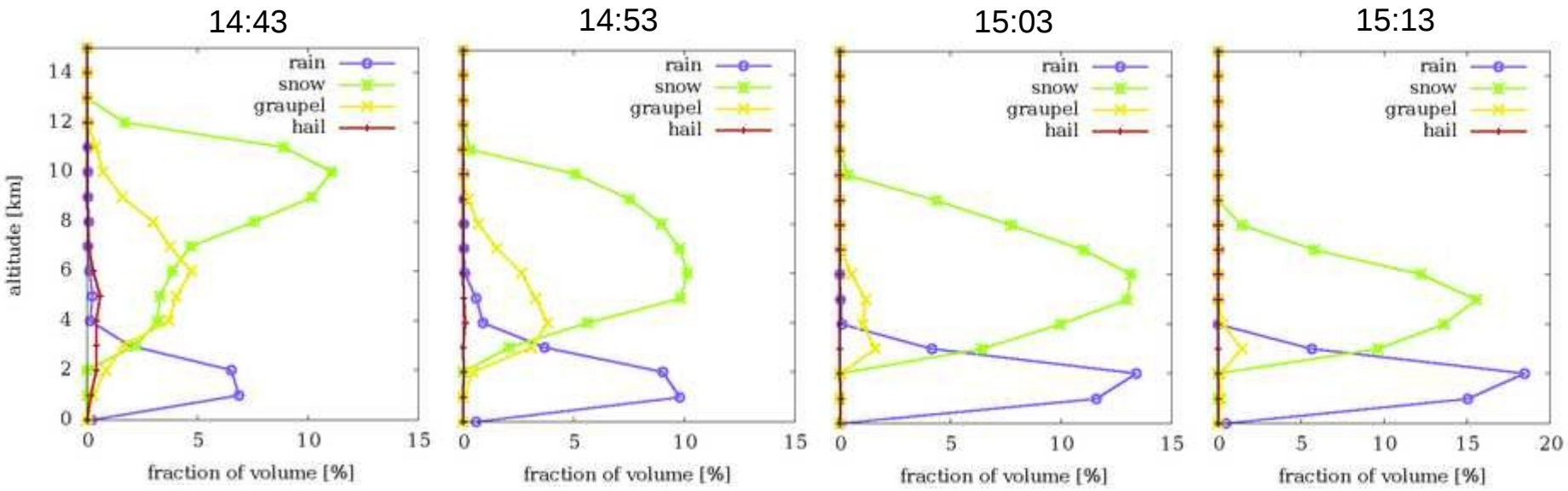


mixing zone (water, ice)

evidence of hail below melting zone:

- HDR (Z+ZDR)
- classification (LDR+ZDR)
- hail spike at reflectivity

Temporal evolution of hydrometeor content



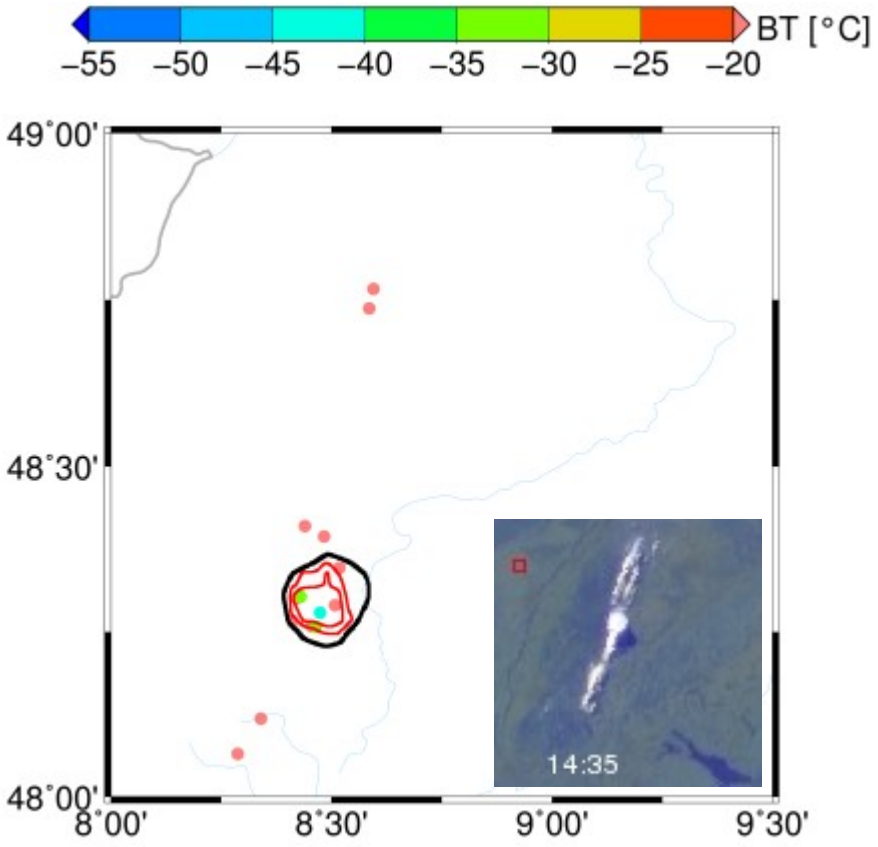
method

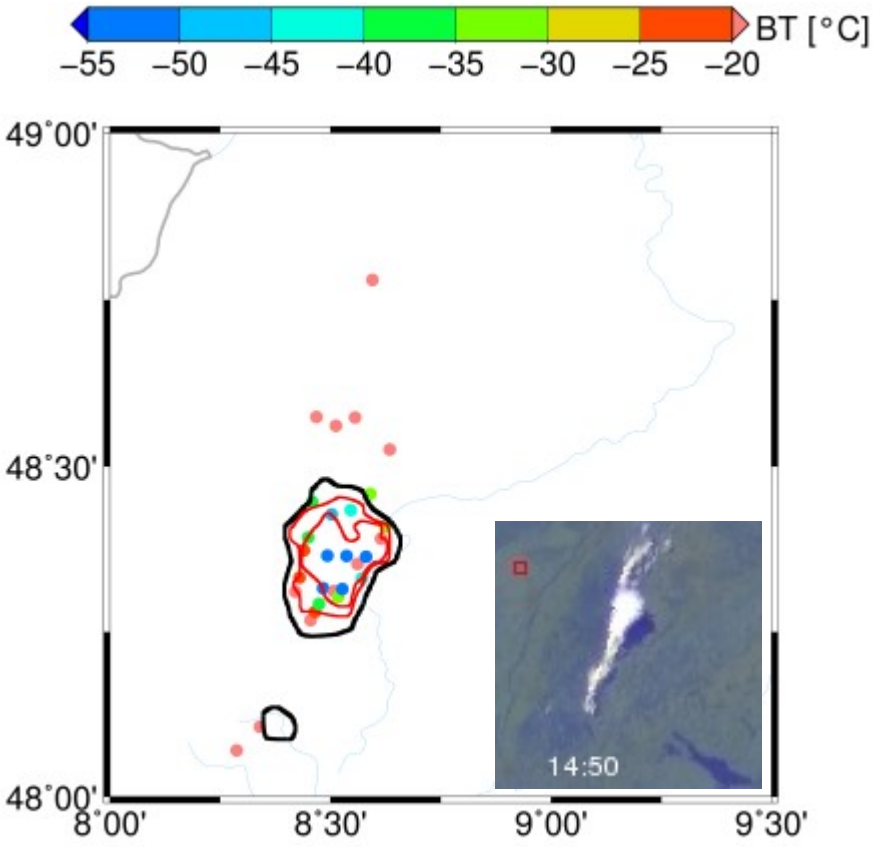
- counting of radar range bins for each hydrometeor type per altitude level (1km)
- normalizing by dividing through total count
- summarizing 5 RHI scans per time interval

results

- fraction of hail is negligible
- Early phase dominated by ice particles (snow, graupel)
- Mean altitude level of ice particles decreases with time, but ice shield seen at photos and MSG data not detected by radar

Cloud-top height

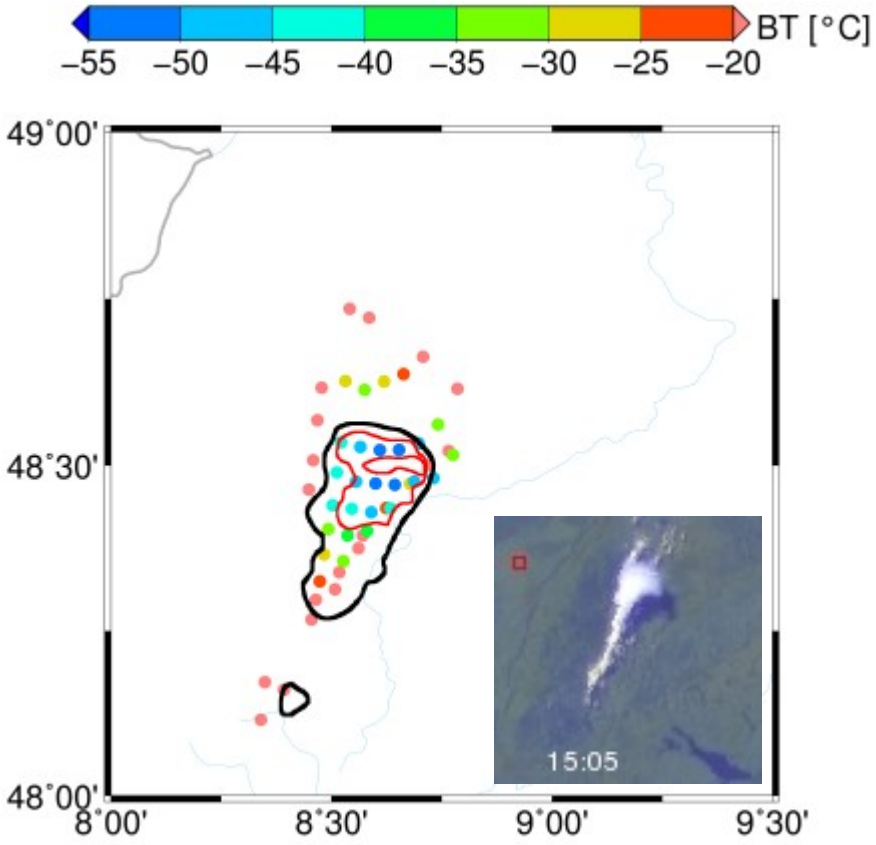


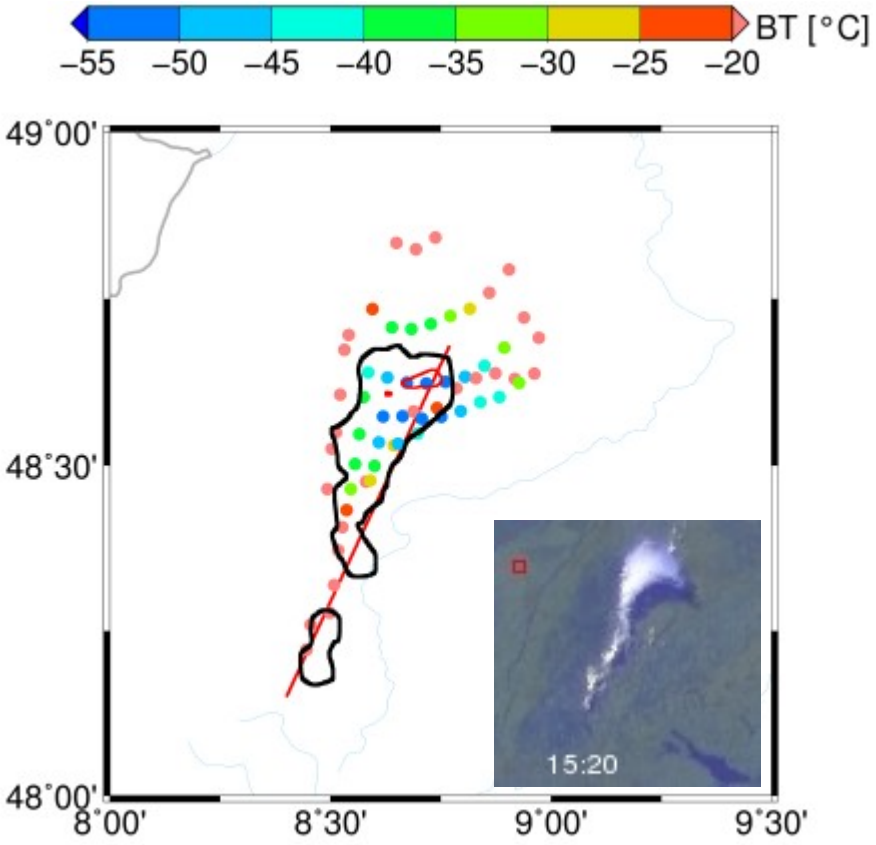


Contours: Triple-radar derived cloud-top heights (8km, 12km, 13km)

Points: Parallax corrected cloud-top positions (MSG IR-channel) with color coded BT

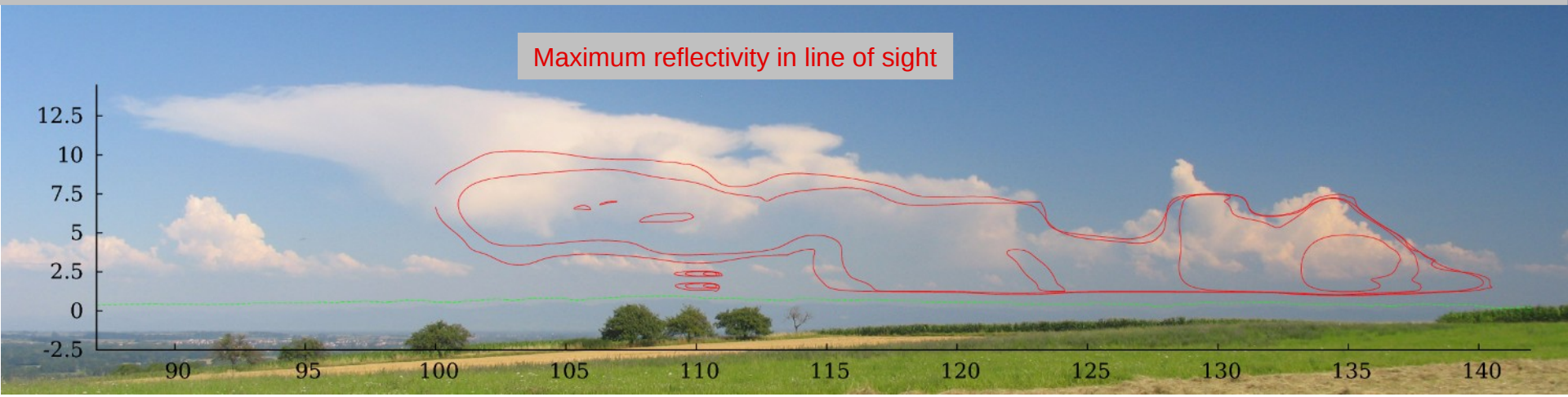
Cloud-top height



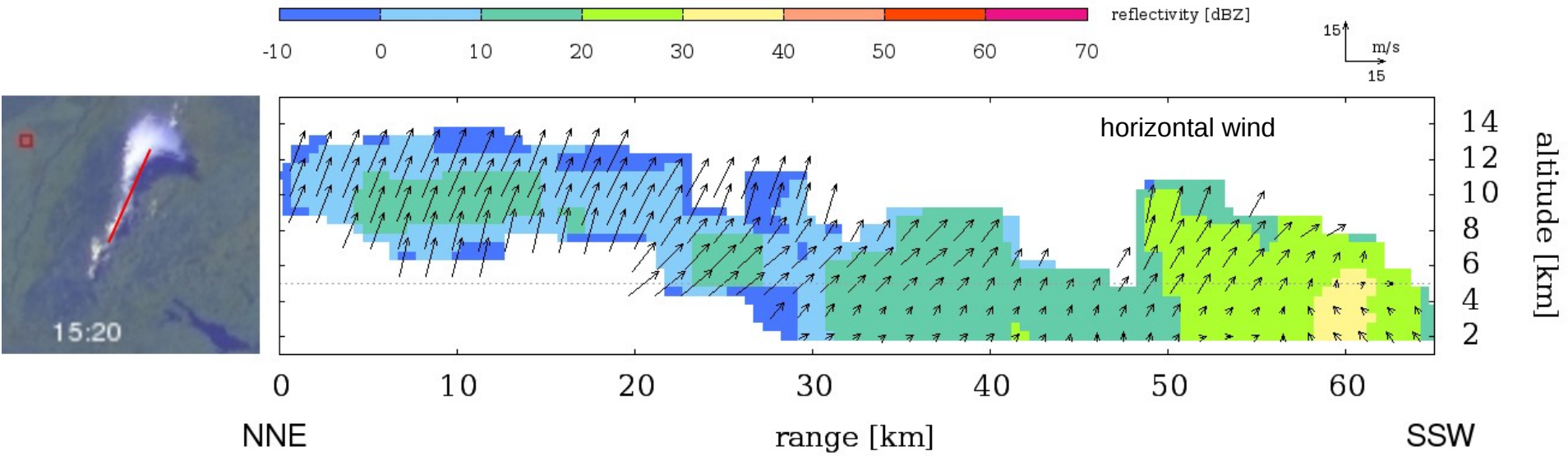


Discrepancy of cloud-top location during the dissipation state

Triple-Doppler results



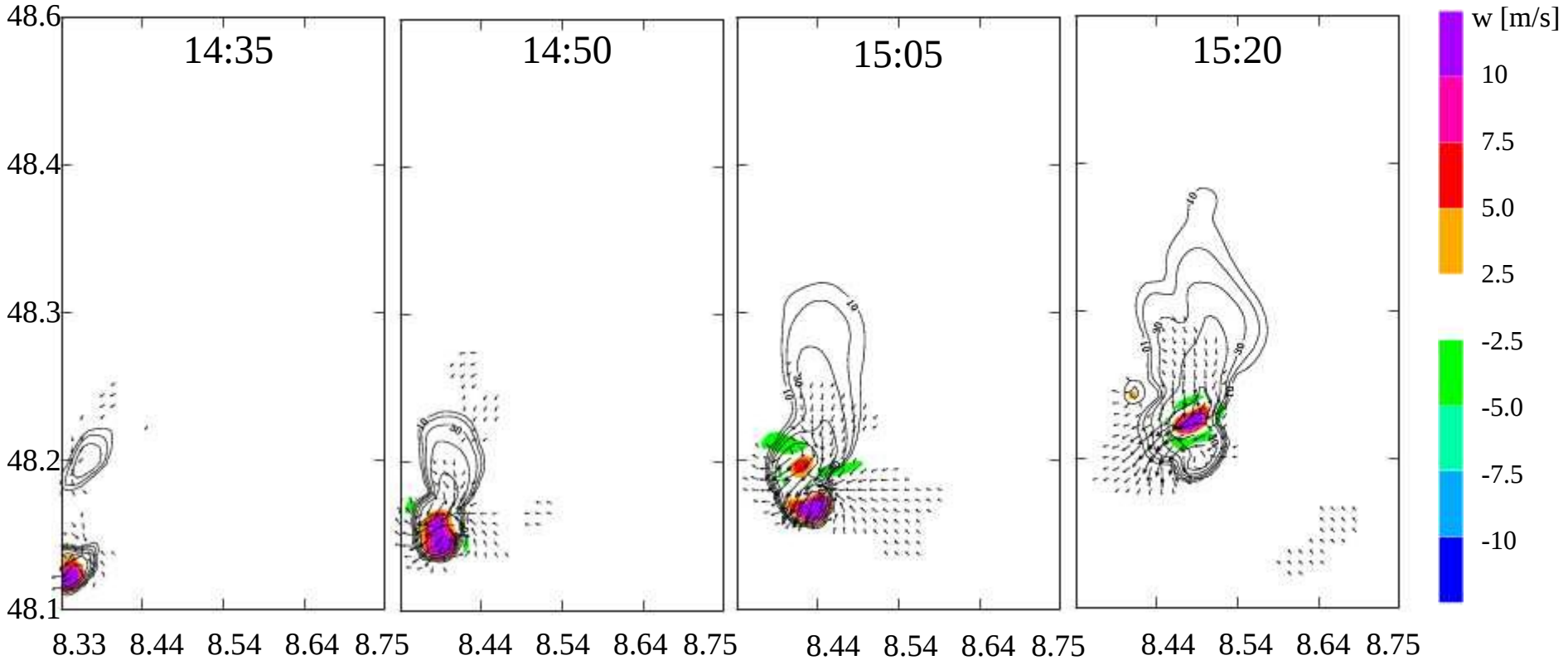
Radar cross section reflectivity



Conclusion

- Documentation of full life cycle by using
  - radar data (inclusive multiple Doppler approach)
  - MSG and lightning data
- Most active phase between 14:35 and 14:45
  - cloud extended to tropopause
  - raised updraft, high cloud dynamic (turbulence), lightning, hail
- Temporal evolution of hydrometeor profiles (consistent with simulations?)
- Discrepancy between radar and satellite & photo due to small ice particles
- Future work: comparison with model results

Outlook: MesoNH-model results from E. Richard



Spatial resolution: 500 m

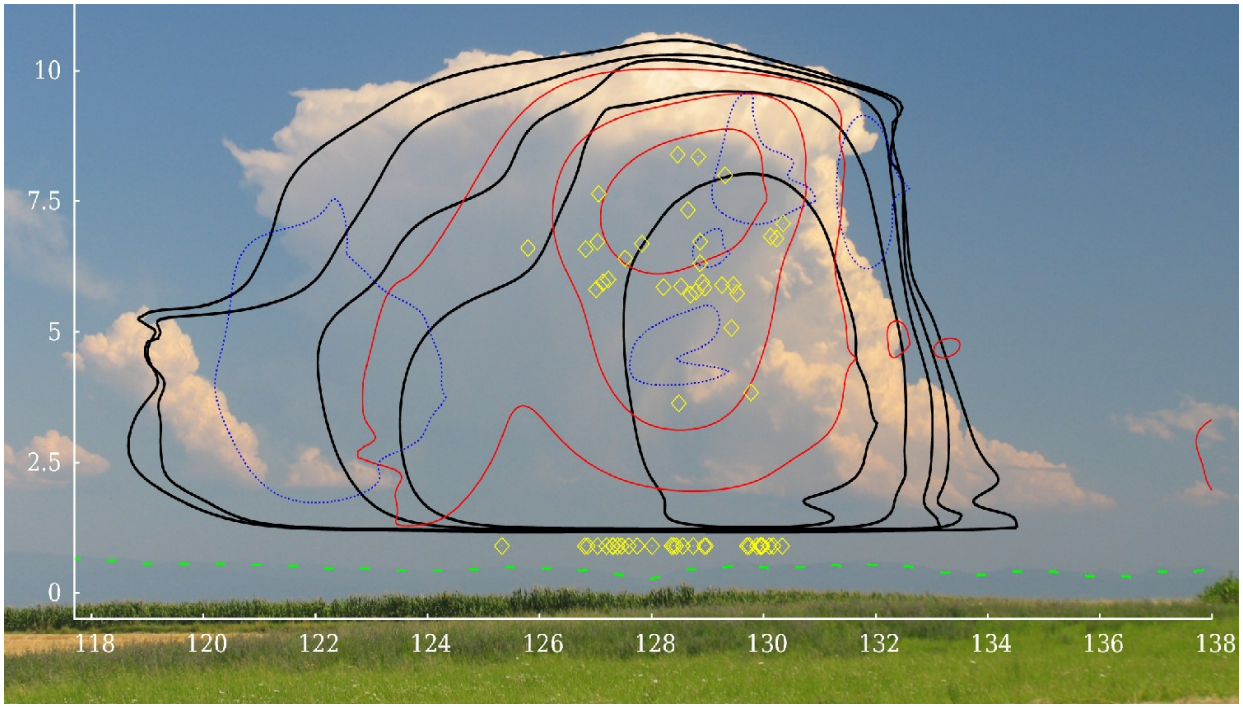
altitude level: 5 km

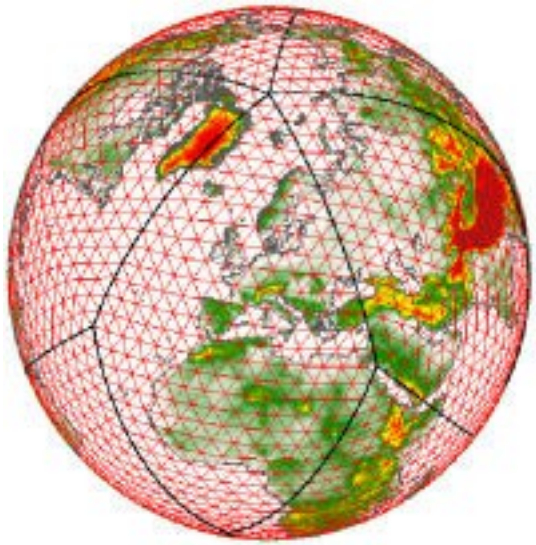
Small spatial (or temporal) discrepancies between model and observation

Different role of southern cell

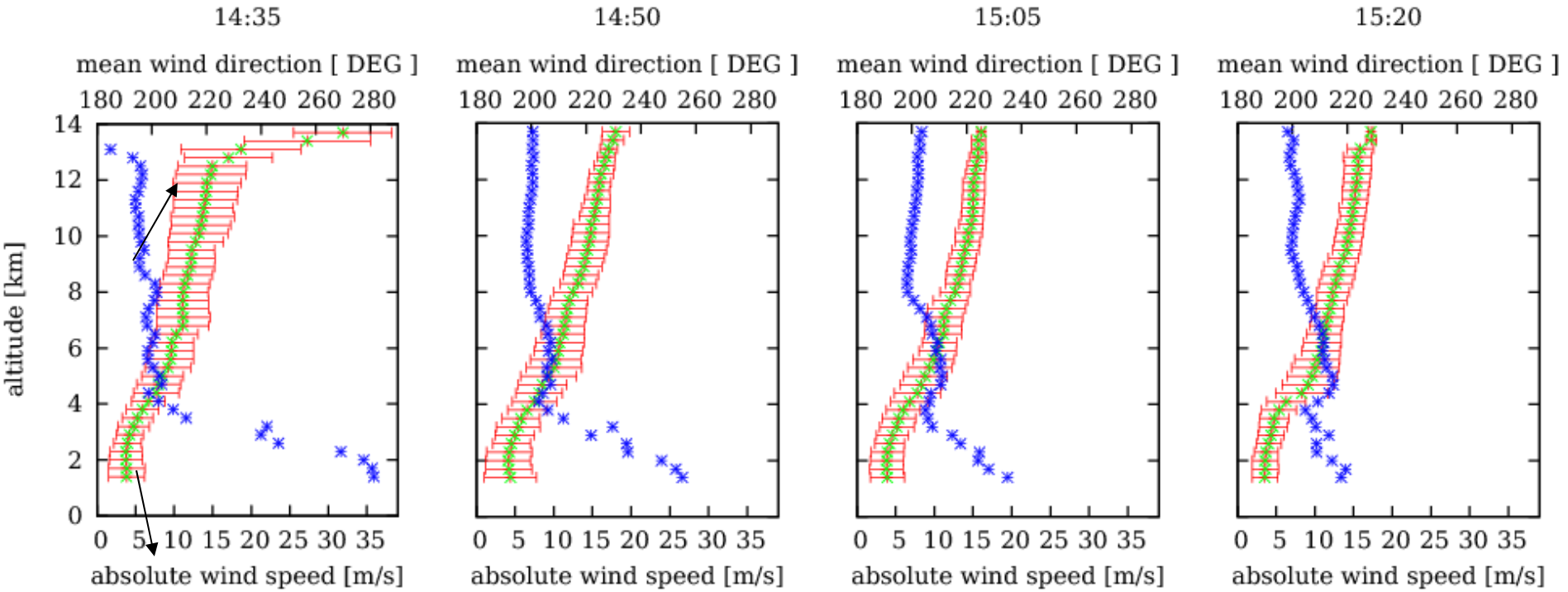
Same inflow and outflow characteristics

Thank you for your attention!





Statistics: Horizontal wind from triple Doppler



Mean horizontal wind speed with standard deviation

Mean wind direction derived from mean u and v wind components

- wind shear decreases during life time
- profiles of mean wind speed ~ constant
- standard deviation of mean horizontal wind correlated with cloud dynamics